CULTURES OF UREDINEAE IN 1916 AND 1917[1]

J. C. Arthur

The present article is the fifteenth in a series of reports[2] by the writer upon the culture of plant rusts, beginning in 1899 and completing nineteen consecutive years. The preparation of the index and summary to the series, as stated in the report for last year, has been delayed, but together with a general retrospect is expected to appear in a succeeding number of this journal. After this, if work of the present character is continued, it will be reported in some other form.

Field Observations in 1916

The writer, by the courtesy of the botanical department of the Indiana Agricultural Experiment Station now under the direction of Professor H. S. Jackson, was enabled to make important observations in the field during 1916, which have proved of the utmost value, not only in detecting the alternate form of certain heteroecious species, but in securing a more adequate conception of the different aspects and range of hosts of particular species when occurring under unlike conditions or in the midst of plant societies composed of different elements.

The first trip of the year was to State College, Pa., in the last days of April, where Dr. F. D. Kern and his associates in the botanical department of the Pennsylvania State College gave every facility for a week's field work. Two excursions in the vicinity are especially worthy of mention, both taken under the personal direction of Professor C. R. Orton. An over-mountain road took us to Charter Oak, where the locality for the amphi-

[1] Presented in part before the Botanical Society of America at the New York meeting, December 29, 1916.

[2] See Bot. Gaz. 29: 268–276; 35: 10–23; Jour. Myc. 8: 51–56; 10: 8–21; 11: 50–67; 12: 11–27; 13: 189–205; 14: 7–26; Mycol. 1: 225–256; 2: 213–240; 4: 7–33, 49–65; 7: 61–89; and 8: 125–141.

sporic *Carex* rust, *Puccinia microsora* Körn., was searched for clues to the alternate host without much success. A twelve-mile ride in another direction to Bear Meadow, an extensive mountain bog, gave opportunity to study the occurrence of *P. uniporula,* and some other difficult *Carex* forms.

On May 13 a western trip of a little over three weeks was begun. The first stop was a few days given to the study of the rust flora of the semi-arid plains between Grant and Ogallala in western Nebraska, where the second telial host for *Puccinia universalis* to be proven by cultures was found.

Next came a few days (May 18–22) at Laramie, Wyo., altitude of 7,500 feet, where the season was not sufficiently advanced for the best field work, but where through the courtesy of Professor Aven Nelson and the assistance of Mr. Edwin Payson an examination of the extensive and valuable Rocky Mountain Herbarium yielded many new hosts and localities for numerous western rusts.

Interesting observations were made (May 23–24) in the vicinity of Ft. Collins, Colo., where every attention was extended by members of the biological staff of the Agricultural College. Professor W. W. Robbins undertook to continue the observation of a number of clumps of *Astragalus* and *Oxytropis* as the season advanced. These plants were growing with masses of aecia-bearing *Euphorbia robusta* intermixed. On October 24 Professor Robbins reported that no rust had appeared on any of the plants of *Astragalus* or *Oxytropis* under observation. From European studies it has seemed probable that the perennial aecia on upright *Euphorbias* and the *Uromyces punctatus* on *Astragalus* and allied hosts, both especially abundant in the Rocky Mountains, were alternating forms of the same rust, but so far neither repeated attempts at cultures nor field evidence have afforded any support to the assumption.

At Windsor, Colo., as the guest of Mr. Geo. E. Osterhout (May 25), a fine display of over-wintered *Puccinia Distichlidis* on *Spartina* was seen in the field with an abundant growth of *Stieronema ciliatum* nearby. Telial material from this locality subsequently gave successful cultures, and on June 12 Mr. Osterhout sent aecia on *Stieronema,* which he obtained from the spot

visited. This is the second culture and the second aecial field collection so far secured.

At Denver the writer was joined by Professor H. S. Jackson. While here (May 26–31) we were under the guidance of Mr. Ellsworth Bethel, whose extensive knowledge of the flora of Colorado and especially his very intimate familiarity with the rust flora of the foot hills and plains about Denver, together with his highly enthusiastic and generous disposition, made the days memorable for the number and important character of the observations. Beside excursions immediately about Denver longer trips were taken through the Municipal Mountain Parks, to Pueblo, and to Boulder, all but the last by automobile with observations along the way. The rust flora of this region is the richest and most varied known to the writer, and the visit resulted in a large increase in knowledge regarding new forms and combinations. The identity of *Puccinia Schedonnardi* with *P. Muhlenbergiae,* the status of *Aecidium Abroniae, Aecidium Liatridis* and the aecia on *Polygonum aviculare,* heretofore erroneously associated with *Uromyces Polygoni,* were established, and much else accomplished. A visit to Mr. Bethel's garden, in which he carries out large numbers of open-air cultures, was most instructive as well as indicative of the highly valuable character of his studies.

The final stop (June 1–2) of the journey was at Manhattan, Kans., where over thirty years ago Professor W. A. Kellerman brought to light a number of forms still imperfectly known. By the aid of Mr. L. E. Melchers and other members of the Agricultural College a fruitful reconnaissance of the vicinity was made, resulting especially in detection of the alternate form for the *Aecidium* on *Allium,* which had tentatively been assigned by different observers to no less than four very unlike telial forms.

Such excursions for observation as those just mentioned have been of inestimable value in securing knowledge for the successful prosecution of the culture work. Without numerous cultures the marvelous advance of recent years in the taxonomic study of American rusts would have been largely impossible. Moreover, without the most varied cultures brought about by observations in widely separated parts of the country the intricate

relationships, transcending all deductions derivable from morphological study alone, must have remained unrecognized, or in so far as dimly apprehended be wholly without demonstration.

A number of correspondents assisted in securing needed material for the season's work, and to them thanks are due. There were available 170 collections with resting spores, and 9 with active spores as in *Aecidium* and *Gymnosporangium*. Some 452 tests were made in a hanging drop to determine the germinating condition of the spores. Only 69 collections of resting teliospores could be brought to germination from which 182 sowings were made, and 17 infections secured. From the 9 collections of fresh spores 12 sowings were made, and 3 infections secured. The work was largely performed by Mr. C. C. Rees, a member of the regular staff of the laboratory.

NEGATIVE RESULTS IN 1916.—Of the various attempted cultures which failed to produce inoculations two are worthy of record.

1. UROMYCES GRAMINICOLA Burr. on *Panicum virgatum* L., sent by Mr. E. Bartholomew from Stockton, Kans., was sown April 25 on *Euphorbia corollata,* and again May 25 on the same host, in both instances with no apparent result. In previous seasons the same species was sown on a number of other hosts,[3] but in the meantime from morphological and distributional data the conclusion had been reached that this form is probably correlated with *Puccinia Pammelii* on the same host, whose aecia are known to be on *Euphorbia corollata.* Other attempts at cultures should be made before abandoning the assumption.

2. PUCCINIA on *Carex Backii* Boott (*C. durifolia* Bailey) obtained by Mr. E. Bethel in February from near Denver, Colo., was sown April 7 on *Ribes Cynosbati, Boltonia asteroides* and *Urtica gracilis,* and again May 15 on the same hosts and on *Eleagnus argentea* and *Artemisia dracunculoides.* The same form obtained by Mr. Bethel in March from Boulder, Colo., was sown April 7, on *R. Cynosbati, B. asteroides,* and *U. gracilis,* and April 15, on *R. Cynosbati, U. gracilis,* and *E. argentea.*

[3] See Jour. Myc. 12: 13. 1906; Mycol. 1: 232. 1909; 2: 220. 1910; 4: 12. 1912.

Another collection sent from Valentine, Neb., by Rev. J. M. Bates, was sown May 26, on *R. Cynosbati, B. asteroides, U. gracilis* and *E. argentea.* All the sowings were without effect. All three collections gave fairly strong germination of the teliospores at the date of sowing.

Cultures have been attempted once before[4] on five hosts, all but one different from the above. The morphological characters of this form approximate those of *Puccinia Grossulariae* on various species of *Carex,* but nothing has yet been proven by cultures.

SUCCESSFUL CULTURES IN 1916 SUPPLEMENTING PREVIOUS WORK.—The culture of the following seven species adds valuable information in each case to the facts previously recorded.

1. PUCCINIA UNIVERSALIS Arth.—Material on *Carex filifolia,* collected by the writer May 18, 1916, at Ogallala, Neb., was sown June 2, on *Artemisia gnaphalodes.* Pycnia were detected June 15, but doubtless appeared earlier, being obscured by the heavy tomentum of the plant, and were followed by a large number of aecia, first seen June 28. This rust has been cultivated a number of times before[5] on various species of *Artemisia,* but only with telial material from *Carex stenophylla. Carex filifolia,* like *C. stenophylla,* occurs on semi-arid plains. It usually grows only three or four inches high, and in dense mats. It is locally known as "nigger-wool" or "black-root," from the tough, tangled mass of fine, black roots, resisting decay for a year or two when turned up by the plow and exposed to weathering.

2. PUCCINIA POCULIFORMIS (Jacq.) Wettst.—This very common stem rust of grasses and grains was grown on *Berberis vulgaris* from two collections made by Mr. G. E. Osterhout, Windsor, Colo., on March 2, one from *Sporobolus cryptandrus,* sown April 23, showing pycnia May 6, but not developing aecia, and the other from *Elymus canadensis,* sown May 15, showing pycnia May 25 and aecia June 6. Another collection on *Agropyron Smithii* made by Mr. E. Bethel, in Denver, Colo., March

[4] Mycol. 2: 248. 1910.

[5] For previous cultures see Jour. Myc. 14: 21. 1908; Mycol. 2: 224. 1910; and 4: 16. 1912.

6, was sown on *Berberis vulgaris* on April 23, and began to show pycnia April 30, and aecia May 4.[6]

3. PUCCINIA RHAMNI (Pers.) Wettst.—A collection made by Mr. G. B. Posey in December, 1915, at Corvallis, Oregon, on *Agrostis* sp., was sown May 11, on *Rhamnus Purshiana,* and showed pycnia in fair numbers May 20, but made no further development, although the leaves remained healthy and in good growing condition for a considerable time.

4. PUCCINIA DISTICHLIDIS Ellis & Ev.—This rust was found May 24 by Mr. Geo. E. Osterhout and the writer in great abundance on over-wintered *Spartina Michauxiana* in a field at Windsor, Colo., and entirely unmixed with any other rust known to occur on the same host. The spores had not yet germinated. Large groups of *Steironema ciliatum* nearby, the supposed alternate host, were already six or eight inches high and free from infection. The teliospores were sown on *S. ciliatum* in the greenhouse at Lafayette on May 30, and gave a heavy infection, showing pycnia June 4, and numerous aecia June 10. This result confirms the work of 1915[7] and establishes the life cycle of the species beyond doubt. On June 12 Mr. Osterhout sent a fine collection of aecia on *S. ciliatum* from the place where the cultural material had been obtained, being the second field collection for the species, the previous one being made in North Dakota.

5. PUCCINIA MUHLENBERGIAE Arth. & Holw. (*P. Schedonnardi* K. & S.).—Telial material of this rust was found May 28 by Professor H. S. Jackson and Mr. E. Bethel, on *Muhlenbergia gracillima,* a low, tufted and fine leaved species growing on the arid plains near Pueblo, Colo., associated with *Malvastrum coccineum,* suspected of being an alternate host. A sowing was made on *M. coccineum* June 2, which gave pycnia June 18, and aecia June 25, both in strong development.

Telial material of *Puccinia Schedonnardi,* on *Schedonnardus paniculatus* was obtained by Mr. Bethel, Professor Jackson and the writer at Pueblo, Colo. After the preceding trial showed signs of success, a striking resemblance was noticed between the

[6] For previous cultures see Jour. Myc. 8: 53. 1902; 11: 57. 1905; 12: 17. 1906; 13: 198. 1907; 14: 16. 1908; Mycol. 2: 227. 1910; and 4: 18. 1912.

[7] See Mycol. 8: 136. 1916.

two grasses in size and habit of growth and also between the gross appearance of the rusts they bore. The resemblance was furthermore found to extend to the microscopic features of the rusts. This led to sowing the teliospores upon *M. coccineum,* which was done June 23, and resulted in production of pycnia June 30, and aecia July 11. Although not so strong development as in the preceding case the gross and microscopic appearances were the same, and left no doubt that *P. Schedonnardi* is to be considered synonymous with *P. Muhlenbergiae,* a species of many races and hosts.[8] The middle of September subsequent to these cultures a letter was received from Mr. E. Bartholomew, of Stockton, Kans., in which he gives the following account of observations, most strongly confirming the conclusion reached from cultures. He says: "Standing in the doorway of the Mt. Nebo Presbyterian Church, three and one half miles south of our home, on June 11, 1916, I noticed, very close to the building, a large number of plants of *Malvastrum coccineum* profusely attacked by *Aecidium malvicola* Arth., and on examining the grasses growing among the *Malvastrum* there was found teleuto material on dead *Schedonnardus,* and on the developing young leaves and sheaths abundant uredo of *Puccinia Schedonnardi!* Continued examinations for several weeks, as the *Puccinia* developed into the III, led me to conclude beyond a peradventure that the aecium is no more nor less than I of this fungus as the grass was infected only in the near reach (not to exceed one rod) of the *Malvastrum.* While I have collected this *Puccinia* several times in the past ten years I have not come across *Aecidium malvicola* since May, 1904 (F. Col. No. 1905)."

6. PUCCINIA SUBNITENS Diet.—This rust is probably the most remarkable known for the number and diversity of its aecial hosts. The present addition of two families to the aecial hosts as previously recorded is entirely the result of information supplied by Mr. E. Bethel, who had made repeated observations of propinquity in the field, and verified his assumptions of relationship by cultural tests in his garden in Denver.

Telial material on *Distichlis spicata* obtained by Professor H.

[8] For previous cultures see Jour. Myc. 11: 51. 1905; 13: 192. 1907; Mycol. 1: 251. 1909; 2: 226. 1910; 4: 18. 1912; and 7: 82. 1915.

S. Jackson at Denver, Colo., May 26, was sown June 9 on *Abronia fragrans* (family Nyctaginaceae) and *Polygonum aviculare,* with infection only on the *Abronia,* on which pycnia began to appear June 15, and aecia June 19, in abundance. A collection on the same host made by the writer at Ft. Collins, Colo., May 23, was sown on *Polygonum aviculare* (family Polygonaceae) June 23, giving pycnia June 30, and aecia July 3, showing strong development.[9]

7. PUCCINIA LIATRIDIS (Ellis & And.) Bethel.—After repeated assurances from Mr. E. Bethel that he had found a rust on *Koeleria cristata* that would produce aecia on *Liatris,* and had cultured it in his garden, and having received material for study, successful sowings were made fully confirming his contention. A telial collection made by Mr. Bethel April 22, at Boulder, Colo., was sown May 4, on *Laciniaria punctata* (*Liatris punctata*), showing pycnia May 15, and aecia May 22. Another collection made by Mr. Bethel and the writer May 30, at Boulder, Colo., was sown on *L. punctata* June 23, showing pycnia July 3, and aecia July 7. The aecia have long passed under the name of *Aecidium Liatridis* Ellis & And., but the telial form has only recently been separated from the several other rusts on *Koeleria* in a paper by Bethel, in which he gives an account of his cultures, but which has not yet been received by the writer in printed form.

SUCCESSFUL CULTURES IN 1916 REPORTED NOW FOR THE FIRST TIME.—The following species have never been cultivated in America or elsewhere, so far as the writer knows.

1. UROMYCES SPOROBOLI Ellis & Ev. (*Aecidium alliicolum* Wint.).—On June 1 the writer in company with Messrs. L. E. Melchers, G. W. Putnam and H. S. Jackson explored a number of centers of infection of *Allium stellatum* showing aecia, found in great abundance in a field adjoining the campus of the Agricultural College at Manhattan, Kans. In one place a few uredinia were found on seedling grass about three inches high, ascertained to be *Sporobolus vaginaeflorus,* while over-wintered telia were

[9] For previous cultures see Bot. Gaz. 35: 19. 1903; Jour. Myc. 11: 54. 1905; 12: 16. 1906; 13: 197. 1907; 14: 15. 1908; Mycol. 1: 234. 1909; 2: 225. 1910; 4: 18, 54. 1912; and 8: 135. 1916.

found on the dead plants of the same annual grass, all pointing to a genetic connection. Hard clumps of earth with the young grass were taken at some distance from the aecial areas and brought to the greenhouse at Lafayette. Whole plants of the *Allium,* in size and appearance much resembling the garden onion, on which were abundant aecia, were also taken, and on June 6 a sowing was made on the seedling grass, resulting in uredinia, first noticed June 21. Another lot of *Allium* plants from the same field, bearing aecia, was sent by Mr. Melchers about two weeks later, and another sowing made June 22, giving uredinia June 29. Neither cultures developed telia, owing to the difficulty in keeping the grass growing properly in the greenhouse. No uredinia appeared on any of the grass not used for inoculation.

The first cultural attempt with the telia of this rust was made fourteen years ago,[10] and again in 1910 and 1912, many hosts being used.[11] In 1912 the attempt was made to follow up observations by Mr. E. Bartholomew at Stockton, Kans., by sowing on *Allium reticulatum,* among other hosts, but with no success. Again this year Mr. Bartholomew sent telia on *Sporobolus neglectus,* which were sown on *A. reticulatum* and *A. canadense,* but again without success. No reason can be assigned for the failures.

2. PUCCINIA VERNONIAE B. & C.—A collection of this rust on dead stems of some undetermined species of *Vernonia,* obtained by Mr. C. H. Crabill at Cliffview, Va., March 9, was forwarded by Dr. F. D. Fromme. The sori were numerous and large, ranging from 0.5 to 1.5 cm. long. A sowing was made on the leaves of an undetermined species of *Vernonia,* which resulted in an abundance of pycnia, and some uredinia, but growth ceased before telia were formed. Exact dates were not secured, but the sowing was made about April 30, and the leaves removed for the herbarium on July 6, bearing pycnia and uredinia. This is the first record for pycnia of this very common rust. The life cycle shows that the species belongs in the genus *Bullaria,* in which it becomes **Bullaria Vernoniae** (B. & C.) comb. nov.

[10] Bot. Gaz. 35: 11. 1903.

[11] See Mycol. 4: 13. 1912; and 7: 66. 1915.

SUMMARY FOR 1916

The following is a complete list of the successful cultures made during the year 1916. Those of the first series are species which have been previously cultured, but those of the second list have never been reported before.

A. SPECIES PREVIOUSLY REPORTED

1. PUCCINIA UNIVERSALIS Arth. Teliospores from *Carex filifolia* Nutt., sown on *Artemisia gnaphalodes* Nutt.

2. PUCCINIA POCULIFORMIS (Jacq.) Wettst.—Teliospores from *Sporobolus cryptandrus* (Torr.) A. Gray, *Agropyron Smithii* Rydb. and *Elymus canadensis* L., sown on *Berberis vulgaris* L.

3. PUCCINIA RHAMNI (Pers.) Wettst.—Teliospores from *Agrostis* sp., sown on *Rhamnus Purshiana* DC.

4. PUCCINIA DISTICHLIDIS Ellis & Ev.—Teliospores from *Spartina Michauxiana* Hitchc., sown on *Steironema ciliatum* (L.) Raf.

5. PUCCINIA MUHLENBERGIAE A. & H. (*P. Schedonnardi* Kellerm. & Sw.).—Teliospores from *Muhlenbergia gracillima* Torr., and from *Schedonnardus paniculatus* (Nutt.) Trel., sown on *Malvastrum coccineum* (Pursh) A. Gray.

6. PUCCINIA SUBNITENS Diet.—Teliospores from *Distichlis spicata* (L.) Greene, sown on *Abronia fragrans* Nutt., and *Polygonum aviculare* L.

7. PUCCINIA LIATRIDIS (Ellis & And.) Bethel.—Teliospores from *Koeleria cristata* (L.) Pers., sown on *Laciniaria punctata* (Hook.) Kuntze.

B. SPECIES REPORTED NOW FOR THE FIRST TIME

1. UROMYCES SPOROBOLI Ellis & Ev. (*Aecidium alliicolum* Wint.).—Aeciospores from *Allium stellatum* Ker., sown on *Sporobolus vaginaeflorus* Torr.

2. PUCCINIA VERNONIAE B. & C.—Teliospores from *Vernonia* sp., sown on the same host.

CULTURES IN 1917

No trips for observation were taken during this year, and the usual amount of time bestowed on the cultures was greatly reduced. About 25 collections with resting spores and 6 with active spores, the latter all forms of *Aecidium,* were available for the tests. About 120 drop cultures were made from the sets of resting spores, showing that 15 of the collections were more or less viable at the time. From the fifteen collections 14 successful inoculations were secured, 103 sowings having been made. The work was partly done by Mr. C. C. Rees and partly by Dr. E. B. Mains, members of the laboratory staff.

NEGATIVE RESULTS IN 1917.—It seems worth while to call attention to three attempts which wholly failed, with the hope that some one may be aided in solving the problems involved.

1. PUCCINIA TRITICINA Erikss. on *Triticum vulgare* Mill. was obtained from the border of a wheat field in September, 1916, by Mr. C. C. Rees, and sown on *Clematis Flammula* L., May 17 following, but with no result. The teliospores, however, were germinating very feebly. The conclusion was reached some two years ago from morphological and other data, that the common leaf rust of wheat is a race of the common *P. Agropyri* E. & E., occurring upon many wild grasses. *P. Agropyri* from *Agropyron glaucum* was cultured on *Clematis Vitalba* L. in Germany by Dietel in 1892. In America cultures have shown races to exist in eastern United States between *Bromus ciliatus* and *Clematis virginiana,* in Colorado between *Elymus canadensis* and *Agropyron Smithii* and *C. ligusticifolia,* in Texas between *Elymus virginicus* and *C. Drummondii,* and in North Dakota between *E. canadensis* and *Anemone cylindrica.* As *Clematis Flammula* and *C. Vitalba* are almost the only common Ranunculaceous plants through the wheat growing regions of southern Europe, northern Africa and western Asia, an area that probably includes the home of the original wild wheat, the assumption is reached that one or both these hosts can be made to bear aecia from *P. triticina* under favorable conditions.

2. PUCCINIA EMACULATA Schw. on *Panicum capillare* L. was sown May 8 on *Euphorbia corollata,* and May 9 on *E. commutata*

with no infection, from material obtained by Prof. H. S. Jackson in southern Indiana. Another collection secured by Dr. E. B. Mains at Lafayette, Ind., was sown May 17 on *E. corollata,* and again May 24, June 5 and 13, on *E. Ipecacuanhae,* with no infection. In each case the teliospores showed fair germination and the hosts were in excellent condition. Judging from morphological and host data these species of *Euphorbia* would be probable aecial hosts, but all attempts at cultures[12] have so far failed. I am indebted to Prof. J. B. S. Norton, botanist of the Maryland Agricultural Experiment Station, for a number of serviceable plants of *E. Ipecacuanhae.*

3. PUCCINIASTRUM HYDRANGEAE (B. & C.) Arth., on *Hydrangea arborescens* L., collected by Dr. E. B. Mains at Lafayette, Ind., March 31, 1917, was sown May 12 on *Tsuga canadensis, Abies balsamea, Abies concolor,* and *Picea canadensis,* with no infection. Although no clues had been obtained from field observation, yet these genera of hosts include all on which any species of *Pucciniastrum* has yet been grown, and the teliospores were germinating freely, so there had been reasonable hopes of success.

SUCCESSFUL CULTURES IN 1917 SUPPLEMENTING PREVIOUS WORK.—The successful attempts to connect the aecia on *Iris versicolor* and on *Rudbeckia laciniata* with telial forms are the culmination of efforts extending over several years, in which a number of persons have aided. Similar efforts to connect the localized aecia on *Houstonia caerulea* and on *Capnoides montanum* have so far been without success, that is, for this laboratory.

1. PUCCINIA MAJANTHAE (Schum.) Arth.—This year for the first time American material of this widely distributed and highly specialized rust has been cultured. The work was first done by Prof. H. H. Whetzel at Ithaca, N. Y., in verification of observations at North Spencer, N. Y., made during the season of 1916 by Prof. Whetzel and Prof. H. S. Jackson. The account of the work has not been published at the time of this writing. Both before and after Prof. Whetzel had obtained his results he sent

[12] For previous attempts see Bot. Gaz. **35**: 12. 1903; Jour. Myc. **8**: 52. 1902; **10**: 10. 1904; **12**: 12. 1906; **13**: 192. 1907; **14**: 11. 1908; Mycol. **1**: 230. 1909; **7**: 65. 1915; and **8**: 127. 1916.

material and gave all possible aid in duplication of his work here in Indiana.

The teliospores from *Phalaris arundinacea,* obtained by Prof. Whetzel at North Spencer, N. Y., Nov. 6, 1916, were sown May 16 on *Iris versicolor,* and again May 17 on *I. versicolor,* and also on *Polygonatum commutatum, Vagnera racemosa, Convallaria majalis* and *Allium stellatum.* On May 19 they were sown on *Polygonatum biflorum* and May 20 on *Maianthemum canadense.* Only infection took place on *Iris,* the first sowing showing copious pycnia on May 21 and aecia on May 30, while the second sowing gave pycnia May 23 and aecia June 1. The only previous similar attempt was made in the cultures for 1910[13] when telial material from South Dakota was sown on *Polygonatum commutatum, Vagnera stellata, Convallaria majalis, Uvularia grandiflora* and *Trillium cernuum* with no infection. It is likely that *Puccinia Majanthae* has aecia on all the hosts named, but if so the occurrence of strongly pronounced biological strains prevented infection in the two tests.

2. PUCCINIA SUBNITENS Diet.—For a number of years the aecia on *Capnoides* (*Corydalis*) known as *Aecidium fumariaceearum* Kellerm. & Sw., have been associated with the telia on *Distichlis spicata* from morphological and host considerations, but the cultures were not made until the present season, although several times attempted. In June Mr. E. Bethel sent aecia on *C. montanum* grown in his garden from teliospores on *D. spicata* secured at Berkeley near Denver, Colo.

Some of the same collection of telia was transmitted by Mr. Bethel and on June 14 the teliospores were sown on *Abronia fragrans, Capnoides montanum* and *Chenopodium album,* with infection only on the last host, giving pycnia June 21, and aecia June 23. Another sowing was made June 21 on *C. montanum,* but gave no infection. Possibly the lateness of season prevented success with the *Capnoides* although the more susceptible *Chenopodium* was infected.

3. UROMYCES SEDITIOSUS Kern.—Observations were made by Dr. F. D. Fromme and the writer in 1914 at Houston, Texas, which appeared to show that this rust sometimes forms aecia on

[13] Mycol. 4: 11. 1912.

Houstonia caerulea, and since then efforts have been made to secure suitable material with which to make tests. With this in view teliospores from a collection on *Aristida ramosissima* made by Prof. H. S. Jackson at Elberfield, Ind., were sown on *H. caerulea,* but without result. Again teliospores from a collection made by Prof. C. D. Learn on *A. basiramea* at Stillwater, Okla., were sown May 24 on *H. caerulea, Plantago Rugelii, P. lanceolata* and *P. aristata,* with infection only on the last two hosts, giving pycnia June 4 and aecia June 7, both in abundance.[14]

4. UROMYCES PERIGYNIUS Halst.—Aecia have been collected on *Rudbeckia laciniata* in the central west from Montana to Wisconsin, Nebraska and Indiana for which telial connection has been sought for some time.[15] Field observations made by Prof. E. W. D. Holway at Excelsior near Minneapolis, Minn., during 1916, pointed definitely to telia on a *Carex.* The material sent by Prof. Holway was *U. perigynius* on *C. sparganioides,* and was sown May 17 on *Solidago canadensis, Aster lateriflorus* and *Rudbeckia laciniata,* with exceedingly abundant infection on the last host, showing pycnia May 21 and aecia May 29. The *Solidago* and *Aster* remained free of rust. Evidently *Rudbeckia* acts as a racial host for this rust parallel with *Aster* and *Solidago.*

SUCCESSFUL CULTURES IN 1917 REPORTED NOW FOR THE FIRST TIME.—Both of the following species introduce questions of relationship which it is impossible at the present time fully to answer.

1. PUCCINIA SPOROBOLI Arth.—Observations were made by Dr. J. F. Brenckle at Kulm, N. Dak., which pointed distinctly to the connection of this rust with aecia on *Lilium umbellatum,* and material consisting of telia on *Sporobolus heterolepis* and bulbs of *L. umbellatum* were sent in the fall of 1916, with which to test the matter. Further telial material was sent the following spring. A sowing was made April 26 and again April 30 and May 1 on a garden lily, *L. elegans* Thunb., closely resembling *L. umbellatum,* the Dakotan plant not being in leaf, but with no infection. On May 16 two sowings were made on the same host and also on

[14] For previous cultures on Plantago see Bot. Gaz. **35**: 17. 1903.

[15] For unsuccessful tests see Jour. Myc. **12**: 12, 13, 14, 25. 1906; **13**: 191, 192, 202. 1907; Mycol. **1**: 229, 230, 251. 1909; **2**: 218. 1910; **4**: 9, 12, 13, 28. 1912.

L. umbellatum, with no infection on the first, and with abundant infection on the latter, showing pycnia May 23 and aecia May 29. Another sowing was made May 29 on *Vagnera stellata, Uvularia grandiflora, Maianthemum canadense, Allium stellatum,* all with no infection, and also on *A. Nuttallii* giving pycnia June 4, and aecia June 9, and on *A. cernuum* giving pycnia June 9, and aecia June 12, both in abundance. Sowings June 5 on *A. stellatum* and *A. canadense* gave no result.

Although the host of this rust is one of the principal prairie grasses of the western plains, yet the rust has been collected only in three localities, one at Decorah, Iowa, in 1884, 1901 and 1902, one at Ewing, northwestern Nebraska, in 1899, and the third a recent find at Kulm, N. Dak. It differs from all other American grass rusts in having the pores of the urediniospores near the hilum.

Last year *Uromyces Sporoboli* E. & E. on *Sporobolus vaginaeflorus* was connected with aecia on *Allium* from Kansas material. The aecia from the two species seem to be indistinguishable by any technical character. The suggestion at once arises that the two forms may be genetically correlated. Examination of the telia supports this hypothesis, for the mesosporic teliospores of the *Puccinia* are indistinguishable in size and appearance from the teliopores of the *Uromyces,* but on the other hand the urediniospores of the *Puccinia* are considerably smaller than those of the *Uromyces* and somewhat thinner walled. The greatest difference, however, lies in the arrangement of pores of the urediniospores. In the *Puccinia* they are three or four and basal, while in the *Uromyces* they are four and equatorial.

A particularly close correlation appears to exist between *Puccinia Cryptandri* E. & B. on *Sporobolus cryptandrus* and *U. Sporoboli,* both in uredinia and telia, although the urediniospores of P. *Cryptandri* are inclined to assume a winter resting condition with thicker walls. Unfortunately no suitable culture of *P. Cryptandri* has yet been made, and the aecia are unknown, but it may be assumed that they will be found to occur on *Allium* or a closely related host.

Putting together what is now known regarding these three forms of rust on *Sporobolus* and comparing with what is known of the

forms of rust on *Carex* going to Ribes, *P. Grossulariae* (Schum.) Lagerh. (*P. uniporula* Orton),[16] we seem justified in assuming that the grass forms in question represent one species made up of morphologico-physiological races, just as the sedge forms appear to do, but the proof is not so complete. The marked differences in the urediniospores of *P. Sporoboli, P. Cryptandri* and *U. Sporoboli,* are all such as can be harmonized with the assumption that the three forms represent only the races of one species, although it does not seem necessary now to go into the required explanation to make the matter perfectly clear. However, for convenient taxonomic reference, and until the relationship is more firmly established, it will be best to treat *P. Sporoboli, P. Cryptandri* and *U. Sporoboli* as independent species.

2. UROMYCES ON SPARTINA.—Field observations by Dr. J. F. Brenckle were made during the spring of 1915 at Kulm, N. Dak., which seemed to indicate connection between aecia on *Vagnera stellata* and the common *Uromyces* on *Spartina.* Such a connection seemed to be strengthened by later observations. On May 31, 1916, Dr. Brenckle says in a letter to the author: "Yesterday I went over my station carefully and found the infected plants of *Smilacina* [*Vagnera*] invariably accompanied by rusted *Spartina.* I noted also a number of well infected leaves, each of which was overhung and scraped on by a rusted leaf of *Spartina.* As the infection of *Smilacina* is only in the pycnial state it probably has not spread away from its original telial source. The *Smilacina* is abundant but the infected plants are sharply confined to those patches also inhabited by the *Spartina.* One such patch had plants of *Smilacina* which were *not* infected. I was disappointed that my theory was not proving correct until I noticed that the *Spartina had no rust.*"

With such strong circumstantial evidence the success of cultures undertaken with telial material supplied by Dr. Brenckle still came as a surprise, for three or four races of the *Uromyces* on *Spartina* are already well known having aecia on three families of dicotyledonous hosts, and no heteroecious rust has heretofore been discovered having aecia on both monocots and dicots.

On May 11 teliospores from *Spartina Michauxiana* were sown

[16] Mycol. 4: 13. 1912; 7: 66, 78. 1915.

on *Vagnera* (*Smilacina*) *stellata, Polygonatum biflorum* and *Steironema ciliatum,* with infection only on the first two, giving pycnia May 18, and aecia May 25, both in the greatest abundance and vigor. Another sowing was made May 19 on *Polygonatum biflorum,* showing pycnia May 28 and aecia June 7, also on *P. commutatum,* showing pycnia May 27 and aecia June 6, and furthermore on the following which were not infected: *Uvularia grandiflora, Maianthemum canadense, Vagnera racemosa, Iris versicolor* and *Trillium recurvatum.* Still another sowing was made May 23 on *Steironema lanceolatum* without infection, and May 29 on *U. grandiflora, M. canadense, V. racemosa* and *V. stellata,* with infection only on the last, only pycnia showing June 6, doubtless owing to the lateness of the season.

Upon studying the microscopic characters of the material here recorded the form is seen to readily fall into the species given in the North American Flora (7: 231) as *Nigredo Polemonii* (Peck) Arth. The aeciospores on *Vagnera* and *Polygonatum* are much larger (18–29 by 19–35 μ) than those on the same hosts which have been assigned to *Puccinia Majanthae* (Schum.) Arth. (15–21 by 16–27 μ), and have thicker walls, being characters by which the two species may be separated. A collection on *Vagnera stellata* from the valley of the Teton in northern Montana was some years ago made a new species under the name of *Aecidium magnatum* Arth., on these same characters. The aeciospores are somewhat larger than those on the other races of the *Uromyces* on *Spartina,* although there is a gradation in size within certain limits for the four races. In fact the four races of this species exhibit not only physiological specialization, but a certain amount of morphological differentiation of both aecia and telia, together with considerable geographical segregation.

For convenience in discussion of these races there would be some advantage to have distinctive names. The following outline will fairly well show the present morphologico-physiological divisions with geographical distribution, and corresponding names.

UROMYCES POLEMONII (Peck) Barth. (*Nigredo Polemonii* Arth.)

Aeciospores 14–19 by 15–23 μ, on *Caryophyllaceae.*
Teliospores generally broad and rounded above.

I. Salt marshes of coast, Nova Scotia (III also in Delaware and Florida), and Southern California (III not known on Pacific coast).....*Uromyces Spartinae* Farl.

Aeciospores 15–23 by 16–26 μ, on *Polemoniaceae.*

Teliospores narrow and mostly acuminate above.

I. Dry plains and thickets, Indiana and Wisconsin to North Dakota and foothills of Colorado (III same).

Uromyces acuminatus Arth.

Aeciospores 16–23 by 18–29 μ, on *Primulaceae.*

Teliospores mostly blunt or truncated above.

I. Moist plains, Central Indiana to Central Wisconsin and foothills of Colorado and Wyoming (III same).

Uromyces Steironematis nom. nov.

Aeciospores 18–30 by 19–35 μ, on *Convallariaceae.*

Teliospores generally blunt or acute.

I. Lake or river banks, Buffalo, N. Y., to Central Montana and Nebraska (III North Dakota)..**Uromyces magnatus** comb. nov.

The collection used for the initial culture may be taken as type of *U. Steironematis.* It was collected at Palmer, Neb., March 22, 1905, on *Spartina Michauxiana* Hitchc., by Rev. J. M. Bates, and was successfully sown May 26, 1905, on *Steironema ciliatum.*[17]

The forms of the teliospores and the habitats of the four forms are to be taken only as the general expression of the races, and are of no real diagnostic value except as associated with other characters. Both acuminate and rounded teliospores can usually be found in the same sorus, but the impression given by a microscopic mount from specimens of the first race is generally that the spores are prevailingly rounded above, from the second race, acuminate, etc.

The aecia of *U. Spartinae* have been collected on *Arenaria* and *Tissa* in Nova Scotia and southern California; those of *U. acuminatus* on *Collomia, Gilia, Phlox* (three species) and *Polemonium,* in Colorado, Indiana, Iowa, Minnesota, Nebraska, North Dakota, South Dakota and Wisconsin; those of *U. Steironematis* on *Dodecatheon* and *Steironema,* in Colorado, Illinois, Iowa, Kansas, Nebraska, North Dakota, South Dakota, Wisconsin and Wyoming; and those of *U. magnatus* on *Polygonatum* (two species) and *Vagnera* (two species), in Illinois, Iowa, Minnesota, Montana, Nebraska, North Dakota, South Dakota and Wisconsin.

[17] Jour. Myc. 12: 25. 1906.

Exsiccati material representing aecia has been issued as follows: for *U. Spartinae* none; for *U. acuminatus,* Barth. F. Columb. *2605,* Barth. N. Am. Ured. *597,* Brenckle, F. Dak. *102,* Ellis, N. Am. F. *1008,* Rab.-Wint. F. Eur. *3637;* for *U. Steironematis,* Barth. F. Columb. *2288,* Brenckle, F. Dak. *134, 259,* Ellis, N. Am. F. *1424,* Sydow, Ured. *2401;* and for *U. magnatus,* Barth. F. Columb. *4162, 4467, 4764,* Barth. N. Am. Ured. *661, 1074, 1170, 1269,* Brenckle, F. Dak. *1, 226,* Griff. West Am. F. *243,* Sydow, Ured. *2298.*

SUMMARY FOR 1917

A. SPECIES PREVIOUSLY REPORTED

1. PUCCINIA MAJANTHAE (Schum.) Arth.—Teliospores from *Phalaris arundinacea* L., sown on *Iris versicolor* L.

2. PUCCINIA SUBNITENS Diet.—Teliospores from *Distichlis spicata* (L.) Greene, sown on *Chenopodium album* L.

3. UROMYCES SEDITIOSUS Kern.—Teliospores from *Aristida basiramea* Engelm. sown on *Plantago aristata* Michx. and *P. lanceolata* L.

4. UROMYCES PERIGYNIUS Halst.—Teliospores from *Carex sparganioides* Muhl., sown on *Rudbeckia laciniata* L.

B. SPECIES REPORTED NOW FOR THE FIRST TIME

1. PUCCINIA SPOROBOLI Arth.—Teliospores from *Sporobolus heterolepis* A. Gray, sown on *Allium cernuum* Roth., *A. Nuttallii* S. Wats., and *Lilium umbellatum* Pursh.

2. UROMYCES MAGNATUS Arth.—Teliospores from *Spartina Michauxiana* Hitchc., sown on *Polygonatum biflorum* (Walt.) Ell., *P. commutatum* (R. & S.) Dietr., and *Vagnera stellata* (L.) Morong.

PURDUE UNIVERSITY,
LAFAYETTE, INDIANA.